Distribution and abundance of benthic habitats within the Sambro Ledges Ecologically and Biologically Significant Area

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DISTRIBUTION AND ABUNDANCE OF BENTHIC HABITATS WITHIN THE SAMBRO LEDGES ECOLOGICALLY AND BIOLOGICALLY SIGNIFICANT AREA

by

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ABSTRACT

Filbee-Dexter, K. 2016. Distribution and abundance of benthic habitats within the Sambro Ledges Ecologically and Biologically Significant Area. Can. Tech. Rep. Fish. Aquat. Sci. 3190: vi + 26p.

This report summarizes the distribution and abundance of benthic habitats and associated communities within the bounds of the Sambro Ledges Ecologically and Biologically Significant Area (EBSA). The area was surveyed using video transects, drop camera observations and dive surveys. Observations were classified into benthic habitats and, when possible, mapped. Dominant benthic habitats in this region include: infralittoral rock reefs dominated by large macroalgae (kelp beds); deep circalittoral reefs dominated by mixed faunal communities, including tunicates fields, sponges, corals and bryozoans; and sedimentary habitats dominated by echinoderms. The Sambro Ledges EBSA containes diverse benthic features and productive habitats, likely due to the many high energy and structural complex rocky reefs, shoals and ledges within the area. Combining field observations with predictive spatial models was an effective way to obtain spatially comprehensive benthic data that can be used in marine protected area (MPA) design, and this approach could be applied to other areas of conservation interest within the Scotian Shelf Bioregion.

RÉSUMÉ

Filbee-Dexter, K. 2016. Distribution and abundance of benthic habitats within the Sambro Ledges Ecologically and Biologically Significant Area. Can. Tech. Rep. Fish. Aquat. Sci. 3190: vi + 26p.

Ce rapport décrit la distribution et l'abondance des habitats benthiques et de leurs communautés dans la zone d'intérêt écologique et biologique de Sambro Ledges (Ecologically and Biologically Significant Area : EBSA). L'étude s'appuie sur des enregistrements vidéo et des relevés de plongée. Ces observations ont permis la classification des habitats benthiques et leur cartographie lorsque que cela était possible. Les principaux types d'habitats benthiques de cette région sont: des récifs infralittoraux dominés par macro algues ; des récifs circalittoraux profonds dominés par des communautés animales mixtes, dont des champs de tuniciers, d'éponges, de coraux, et de bryozoaires ; et des habitats sédimentaires dominés par des échinodermes. Cette grande diversité d'habitats peut être expliquée par la complexité structurelle des récifs et fonds marins de Sambro Ledges. L'approche combinatoire d'observations *in-situ* et de modèles multidimensionnels prédictifs utilisée lors de cette étude pourrait être appliquée aux habitats benthiques d'autres EBSAs de la bio région du plateau néo-écossais.

PREFACE

At the request of DFO Science and the Oceans and Coastal Management Division (OCMD), characterization of the substrate and benthic communities off Sambro, Nova Scotia was completed using video surveys conducted between 2012 and 2015. To better estimate the geographic location and extent of these benthic habitats, additional observations across the spatial bounds of the Ecologically and Biologically Significant Area were obtained from drop camera surveys conducted in September 2016 and funded by WWF-Canada, and are included here.

INTRODUCTION

Canada has committed to establishing a network of marine protected areas (MPAs) that will increase the percentage of Canada's protected coastal and marine areas to 5% by 2017 and 10% by 2020 (BiodivCanada 2016). A well-designed MPA network should: 1) protect examples of all types of biodiversity, 2) help maintain ecological processes, 3) protect rare or endangered species, 4) protect highly sensitive habitats and nursery habitats, and 5) increase resilience to direct effects of climate change. Meeting these targets necessitates a systematic, data-driven approach to MPA network development. DFO Science has outlined advice on data requirements and methods for the design of MPA networks (DFO 2012; DFO 2013). Compiling ecological data for coastal regions is an important initial step in this process.

The Scotian Shelf Bioregion is one of the five priority bioregions identified for MPA network development. Quantitative and spatially complete information on coastal habitats along the Scotian Shelf is limited. Due to this data paucity, Ecologically and Biologically Significant Areas (EBSAs) selected using expert opinion (DFO 2006; Hastings et al. 2014; Kenchington 2014), are being used to identify coastal regions that could be included in a MPA network.

The Sambro Ledges EBSA, which includes Sambro Island and the surrounding ledges (Figure 1), is currently a candidate for inclusion within the proposed MPA network for the Scotian Shelf Bioregion. The dominant benthic habitats and associated communities have not been described for this EBSA.

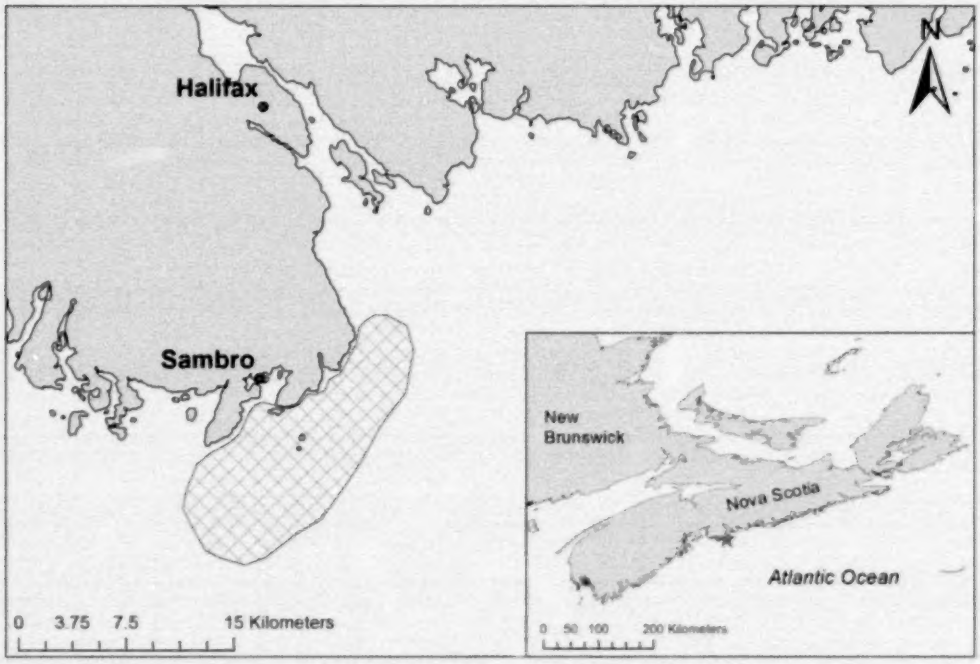

Figure 1. Map showing location of the Sambro Ledges EBSA (hatched polygon).

Predictive models are commonly used by conservation managers to estimate the spatial extent of species that are of conservation interest (e.g. Tittensor et al. 2009; Rooper et al. 2014; Murillo et al. 2016). These models, often termed species distribution models (SDM) or habitat distribution models, describe the relationship between point observations of a species and environmental or spatial characteristics of these points (Franklin 2009), and can be used to predict the continuous spatial distribution of species (Evans et al. 2011). In this report, SDM was used to create predictive maps of key ecological habitats within the Sambro Ledges EBSA using observations from video surveys and environmental data layers of the area.

The report has the following objectives:

1. Summarize observed physical, biological and ecological features and map their geographic location and extent.

2. Provide recommendations for adjusting EBSA boundaries and further sampling required.

METHODS

VIDEO SURVEYS

Observations of benthic habitats were obtained from video surveys conducted between 2010 and 2015 (Filbee-Dexter & Scheibling 2016). Video surveys used a digital video camera (Ocean Systems Deep Blue Pro II Color, Sea View Underwater Search Equipment) attached to a depressor dive wing (JW Fishers DDW-1 Deep Dive Wing, Sea View Underwater Search Equipment) towed at an average speed of 0.59 m s^{-1} from a 7-m motorized research vessel and maintained ~ 2 m above the seafloor using a hydraulic slip-ring winch (Shark Marine Technologies). To account for the positional offset between camera and vessel, an acoustic transponder was used to directly record depth of the camera (Tracklink 1500 USBL tracking system, LinkQuest). The average length (± SD) of transects was 200 m (± 98 m) (Table 1). Video surveys began on shallow reefs or submerged shoals and extended perpendicular to shore over adjacent bedrock shoals or sedimentary habitats to a maximum depth of 96 m (Table 1, Figure 2). In total, 15 transects were conducted covering approximately 3070 m^2 of total seafloor. Video transects were targeted for kelp beds, so the prevalence of these habitats observed in these surveys was likely an over-estimate of their actual abundance within the EBSA.

To better understand the geographic location and extent of different benthic habitats, additional observations across the spatial bounds of the EBSA were also obtained using drop camera surveys conducted in September 2016 by WWF Canada. These surveys were completed using a high resolution video camera (Splashcam Sidewinder 360, Ocean Systems) deployed at 90 randomly selected locations within the bounds of the Sambro Ledges EBSA (random locations generated using R package sp, Figure 2). During each drop camera survey, the sea floor was recorded for 1 minute using both a downward angle and 360 lateral view of the benthic habitat. The boat remained stationary during the

survey, so no positional offset was required. The random survey design was selected to complement spatial information from video transects and to best enable predictive mapping of benthic habitats in the area.

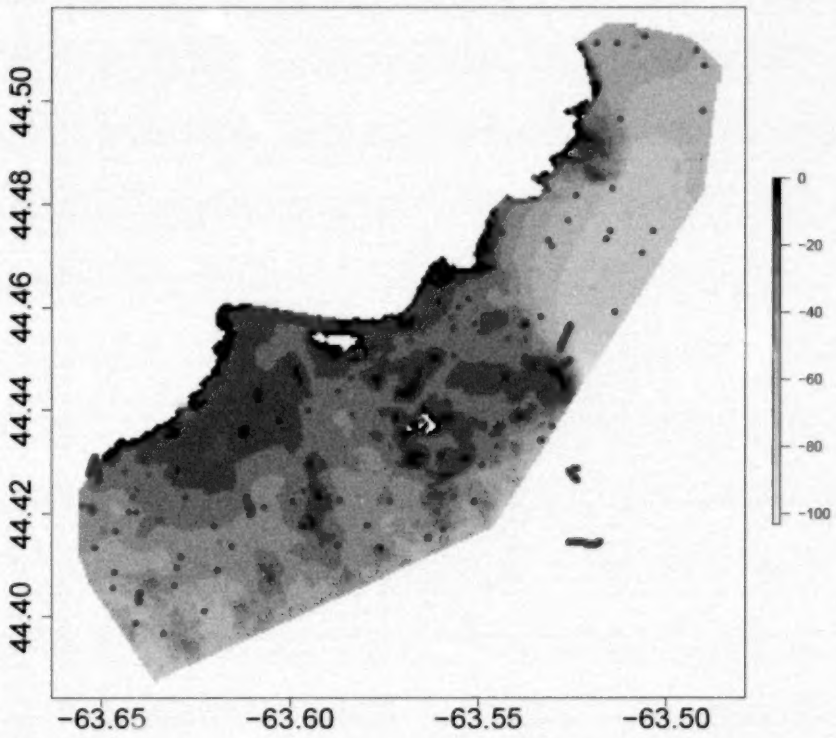

Figure 2. Video and dive survey sites within the EBSA and surrounding area. Gray fill indicates depth (m). Blue lines represent video transects and blue points represent drop camera surveys. Black areas represent shoals and submerged ledges.

Table 1. Locations, transect length, maximum depth, start and end coordinates and dates of video survey within the Sambro Ledges EBSA and surrounding area.

Date	Location	Lat. Long. Start	Lat. Long. End	Max. Depth (m)	Length (m)
27.11.2011	Hennessy Bank	44.428122 -63.525692	44.426338 -63.523644	52	123
27.11.2011	Pennant	44.430934 -63.651532	44.427607 -63.653320	39	201
27.11.2011	Hennessy	44.428752 -63.524677	44.428604 -63.523563	61	50
27.11.2011	Hennessy	44.414448 -63.525755	44.414441 -63.516530	59	365
5.02.2014	Splitnose	44.477241 -63.546362	44.474141 -63.543595	28	206

Date	Location	Lat. Long. Start	Lat. Long. End	Max. Depth (m)	Length (m)
5.02.2014	Gull Rock	44.444875 -63.569627	44.448137 -63.570130	21	210
11.07.2012	Sambro I	44.418973 -63.52037	44.420506 -63.517276	40	220
19.05.2013	The Sisters	44.448708 -63.527692	44.449662 -63.525502	51	130
19.05.2013	Black Rock	44.451590 -63.528310	44.456380 -63.525572	78	331
9.09.2015	Paddle I.	44.439199 -63.625671	44.434932 -63.621727	18	300
9.09.2015	Pennant	44.423236 -63.611343	44.197077 -63.610544	37	220
9.09.2015	Seven Island	44.443723 -63.675768	44.449688 -63.676136	42	325
9.09.2015	Mars I	44.434841 -63.719119	44.432029 -63.715391	39	261
9.09.2015	Mars I	44.411080 -63.756218	44.432029 -63.715391	91	89
9.09.2015	Mars R	44.401917 -63.687895	44.400500 -63.687535	63	80
9.09.2015	Pennant	44.404686 -63.639684	44.402870 -63.640016	54	96

VIDEO ANALYSIS

All video transects were viewed in iMovie (version 9.0.4, Apple) in real time, and substrate type, algal community, and faunal presence were recorded in an Excel macro, synchronized with the video time and the tracklink record. The video of the seafloor from the drop camera surveys was classified as single data points, based on the dominant habitat type observed directly under the camera at each location. Substrate was classified into 7 categories using simplified Wentworth classifications: bedrock, boulders, cobbles, coarse sand, fine sand, sand covered bedrock, and mixed rock and sediment (Wentworth 1922; rock and grain size were estimated using scale lasers). Observations of anemones, ascidians, corals, sponges, echinoderms (*Ophiopholis aculeata*, *Echinarachnius parma*, and sparse *Strongylocentrotus droebachiensis*), mussel beds, and faunal turfs (which included mixed bryozoans, hydroids, and sponge communities) were recorded in the Excel macro. Observations of dense aggregations of *S. droebachiensis* (sea urchin barrens) and *Boltenia ovifera* (tunicate fields) were also recorded. Macroalgae were classified into the following groups: turf-forming algae, *Laminaria digitata*, mixed *L. digitata* and *Saccharina latissima*, *Desmarestia* spp., mixed *S. latissima* and *Agarum clathratum*, mixed *A. clathratum* and red foliose algae, and dense red foliose algae. Additional features, such as observations of mobile species, associated fauna and macroalgal cover were described from video observations. These measures were used, as well as environmental characteristics (depth and energy level), to describe the main

benthic habitats present within the EBSA.

To assess the diversity of benthic habitats found within the EBSA, I used a detailed habitat classification system based off the European Nature Information System (EUNIS) classification scheme. EUNIS was developed by the European Topic Centre for Nature Protection and Biodiversity (ETC/NPB in Paris) for the European Environment Agency (EEA) and the European Environmental Information Observation Network (EIONET) (Davies et al. 2004). This classification framework was selected because it enables fine-scale classifications of abiotic and biotic data, has undergone rigorous peer review, and can be applied to marine ecosystems in the North Atlantic. It also may facilitate future collaboration with conservation initiatives across the North Atlantic Ocean.

EUNIS is a hierarchical system that classifies habitat into increasingly detailed categories. The broad-scale marine categories that apply to the habitats within the Sambro Ledges EBSA include: 1) subtidal sediment (coarse and fine sand, mixed rock and sediment); 2) infralittoral rock (shallow subtidal rock that supports dense seaweed); 3) circalittoral rock (subtidal rock from lower limit of infralittoral to the maximum depth where photosynthesis takes place, often divided into 2 zones: circalittoral and deep circalittoral); and 4) subtidal sediment dominated by macroalgae. Within each of these broad categories habitats are grouped into more detailed categories based on dominant macroalgal and/or faunal communities. The hierarchical structure enables coarse classification of benthic habitats using abiotic data layers (obtained from bathymetric data and remote sensing) followed by fine-scale classification using biological data (obtained from observations or collections). In this report benthic habitats were classified using observations of biological communities, depth, bottom type and energy level for each survey point. Wave and current data were available at too coarse a resolution to use, so habitats within the EBSA were broadly classified as high energy due to exposure to open ocean swells and strong wind-driven wave action caused by large fetch (Davies et al. 2004). The boundary between circalittoral and deep circalittoral zones was determined by presence or absence of turf or foliose red algae.

DATA LAYERS FOR PREDICTIVE MAPPING

Observations of the seafloor and high resolution environmental data available for the area were used to generate predictive maps of dominant benthic habitats within the Sambro Ledges EBSA (Figure 2, Table 2). A coastal map of bottom type and a digital elevation model (DEM) of 30-m cell resolution created using a combination of contour, sounding and multibeam data from the Canadian Hydrographic Service and the Nova Scotia Geomatics Centre were obtained from the Fisheries and Oceans Canada (DFO) (Greenlaw et al. 2013). The processed bathymetry data were used to produce 5 additional layers of the seafloor using Spatial Analyst and Benthic Terrain Model tools (Wright et al. 2005): slope; planar, profile and standard curvature; and bathymetric position index (BPI). Standard curvature describes concavity (e.g., trough or depression) or convexity (e.g., ridge) of the seafloor, planar curvature describes concavity/convexity measured perpendicular to the aspect of the slope, and profile curvature describes concavity/convexity measured parallel to the aspect of the slope. BPI is a measure of the

depth of a location relative to the depth of the surrounding area and describes concavity or convexity of a circular area of seafloor. The offshore distance of each cell was calculated as the shortest length from the centre of a grid cell to shore (km) using ArcGIS. Also included was a layer of probability of hard substrate created using observations from the same video transects used in this study and the above predictor variables (Table 3, 4). In total, 8 environmental variables were used as predictor variables for the habitat distribution models.

Table 2. Data sets used to develop predictive models. All raster data sets were resampled to 30 m resolution to match DEM and derived rasters.

Occurrence data	
Habitat/Species	Presence and absence observations of habitats or species from video surveys
Predictor variables	
Depth	Digital elevation model (DEM) created using a combination of (DEM) multibeam, contour and sounding data from the Canadian Hydrographic Service (CHS) and the Nova Scotia Geomatics Centre (30-m resolution)
Slope	Derived from DEM in ArcGIS (v10.2, ESRI, Inc.)
Standard curvature	Derived from DEM in ArcGIS
Planar curvature	Derived from DEM in ArcGIS. Created using aspect raster also derived from DEM
Profile curvature	Derived from DEM in ArcGIS. Created using aspect raster also derived from DEM
Bathymetric Position Index	Derived from DEM in ArcGIS using 4 cell neighbourhood. Inner radius = 1 cell
Distance offshore	Derived using euclidean distance function in ArcGIS Spatial Analyst from Nova Scotia Coast high resolution line data
Bottom type	Seabed type determined using surficial geology, geomorphology, CHS and substrate samples from DFO in the coastal western Maritimes Region (Greenlaw et al. 2013)
Rock	Probability of rock substrate created using predictive model with 12.6% misclassification error

MODEL CALIBRATION AND EVALUATION

Habitat distribution models were created using a random forest model (RF) (Breiman 2001; Cutler et al. 2007). RF is a machine learning algorithm that classifies data into categories using multiple classification or regression trees, with each run using a subset of predictor variables to classify a subset of response data. This model type was selected because it is ideal for cases with noisy, nonlinear data and strong interaction effects, it does not overfit complex models, and it has high performance in predicting habitat distributions (Li and Wang 2013). RF models are also not as influenced by spatial autocorrelation compared to generalized additive models or generalized linear models (Marmion et al. 2009). In this study RF models were run using 3 predictor variables for each split, and pruning trees after 3 splits. Six habitats of interest were the focus: kelp

beds, tunicate fields, red algae-dominated reefs, mixed faunal reefs, sedimentary habitats with macrofauna, and rock substrate. For each of these response variables, the occurrence (presence/absence) of the habitat was estimated using RF models (binary response: 1: >50% of trees in RF model classified point as a presence, 0: <50% of trees in RF model classified point as a presence). Model performance was assessed by fitting the RF with training data and evaluating its predictions for sites of known habitat type using testing data (termed 'out of bag' data in RF). Error rate between training and testing data was termed misclassification error. Variable importance was assessed using a GINI index calculated by the randomforest package in R (Breiman 2001). To account for unbalanced presence/absence data, which can place too much weight on reducing false negatives and lead to elevated rates of false positives, equal weight was assigned to the presence and absence errors in the RF model. This ensured that the likelihood that the model correctly predicted an absence was similar to the likelihood that the model correctly predicted a presence. This correction increased the overall model error slightly, but it was determined that this trade-off was worth the added sensitivity. The occurrence of the above habitat types within the larger EBSA was predicted by using the RF models and maps of the predictor variables for the EBSA and surrounding region. The results of these predictive distribution models are presented as maps showing the binary occurrence (presence/absence response that was used to assess model performance) and the probability of occurrence (proportion of trees in the RF model that classified a point as a presence) of the habitat.

DIVE SURVEYS

Dive surveys at 8 m depth at Shag Rock and Gull Island were completed using SCUBA. At each site divers measured kelp density (*Saccharina latissima*, *Laminaria digitata*, *Agarum clathratum*) in 8 haphazardly placed 0.25 m^2 quadrats. Divers also conducted fish and invertebrate surveys along 2 transects at each site, counting and identifying all fish, crabs and lobsters within 4 m (2 m to each side) of a 30 m transect line.

RESULTS

OBSERVED PHYSICAL FEATURES

The seafloor within the EBSA extended to 103 m depth. Of the total observations of the seafloor, 54% were bedrock or boulder fields, 30% were coarse or fine sand, and 16% were mixed sediment, cobbles, or rock covered sand (Figure 3). Geomorphology of the area was complex, consisting of steeply sloping bedrock shoals, small islands, submerged ledges, and flat or gently sloping sediment. The western part of the EBSA was relatively shallow with many rock shoals. The northeastern region of the EBSA consisted of a uniform sediment shelf that extended off Chebucto head towards the entrance of Halifax Harbour. The deepest regions of the EBSA were predominantly sand and mixed rock and sand substrate. The steepest ledges within the EBSA were found along the eastern edge, adjacent to The Sisters, a shoal located east of Sambro Island (Figure 2).

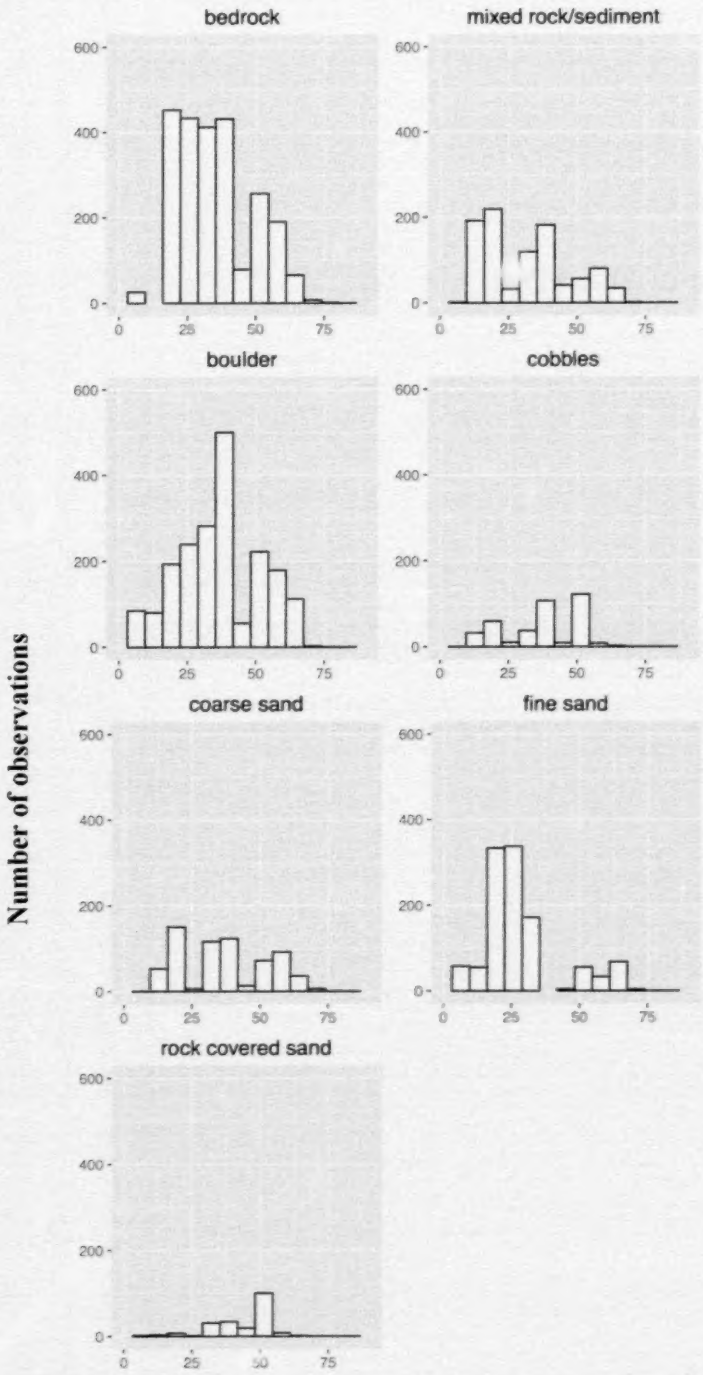

Figure 3. Prevalence of substrate type across depth.

BIOLOGICAL FEATURES ON HARD SUBSTRATE

Biogenic habitats observed within the area included stalked tunicate fields, kelp beds, and mixed sponge, coral and bryozoan communities. Predictive distribution maps indicate that these biogenic habitats cover approximately 43 ± 4% of the total areal extent of the EBSA.

Kelp beds: Kelps occurred between 3 and 78 m depth, with the majority of observations between 10 and 35 m. *Laminaria digitata* dominated depths of 10–20 m, and *Saccharina latissima* and *Agarum clathratum* dominated between 20 and 40 m, which was the lower limit of dense seaweed growth. These habitats occurred on bedrock (60%), boulders (30%), mixed rock and sediment (8%), and cobble (2%). Kelp beds within the EBSA were relatively healthy, with high canopy cover and low epiphyte cover (based on visual estimates of 50–100% canopy cover and < 10% epiphyte cover from video surveys). Turf algae-dominated reefs were observed around depths 5–12 m and were only found at 9 sites. Predictive distribution maps of the occurrence of kelp beds estimated that these habitats covered an estimated 19% of the total extent of the ESBA (Figure 4, Table 3). An error rate of 7.7% was associated with these predictions (Table 4).

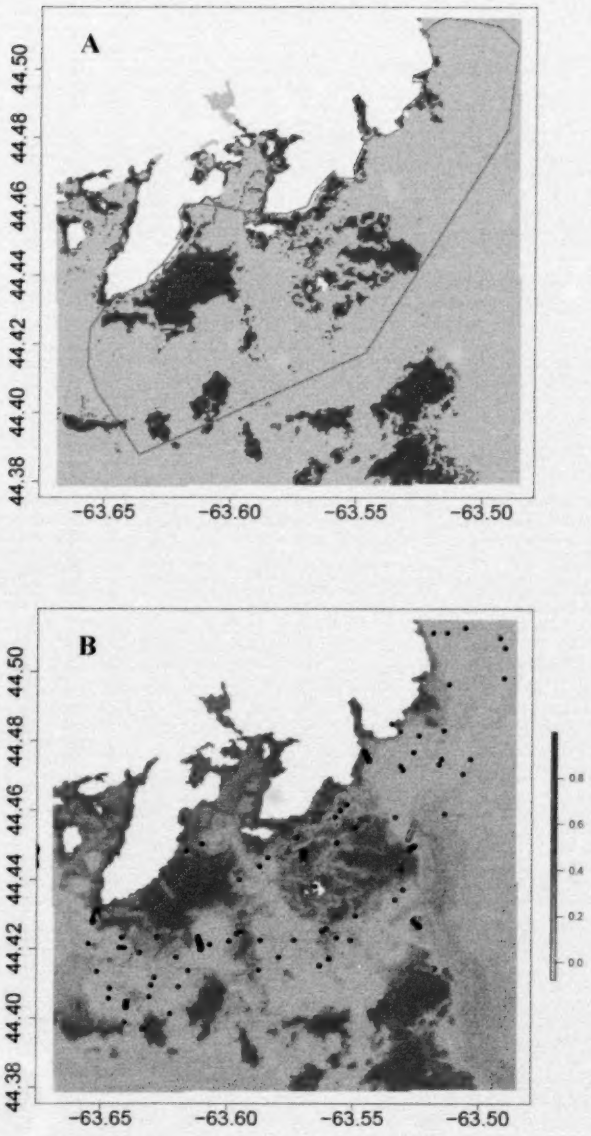

Figure 4. Predicted maps of kelp beds (blue). Maps show: A) the binary occurrence (presence/absence) of kelp beds, which was used to assess model performance; and B) the probability of occurrence of kelp beds, calculated as the proportion of trees in the RF model that classified a point as a presence. Red line shows bounds of EBSA. Points show locations of presence (red) and absence (black) observations from video surveys.

Table 3. Prevalence of rock reefs, and biogenic habitats within the bounds of the EBSA. Observed prevalence is calculated as the number of observations of the habitat type out of the total observations from randomized drop camera surveys (n = 90) and targeted video surveys (n = 4926). Estimated prevalence is the percent of the total EBSA (n = 30,221 grid cells) predicted to contain each habitat type from the SDMs. One grid cell is 30 by 30 m.

Habitat type	Observed prevalence (%) from point surveys	Observed prevalence (%) from video transects[1]	Estimated prevalence (%) from habitat distribution models[2]
Rock reefs	54.4	60.0	55.7 ± 6.1
Tunicate fields	13.3	4.6	10.0 ± 1.7
Kelp beds	23.3	30.1	19.1 ± 1.0
Red algal reefs	21.1	8.9	5.3 ± 0.6
Mixed faunal communities	10.0	9.5	8.4 ± 0.6

[1]The video transects were targeted for kelp beds so the prevalence of these habitats in video transects is likely higher compared to the prevalence of kelp beds within the EBSA. [2]Error estimated using percentage misclassification of presence predictions from RF model (Table 4).

Table 4. Accuracy measures and confusion matrix from RF models of occurrence of benthic habitats and of rock substrate. Each point represents an observation of presence or absence of benthic habitat or rock substrate from video transects or drop camera surveys. Class error describes the sensitivity (rate of false negative) and specificity (rate of false positive) of each model in predicting the response. Error rate represents the out of bag misclassification rate of the RF models. The variable importance of the 3 most important predictor variables used in each RF model are shown.

Observations	Predictions		Total n	Class error	Error rate	Predictor	Importance
Kelp beds	Absence	Presence			7.7	Distance	459
Absence	3191	314	3505	0.09		BPI	453
Presence	74	1437	1511	0.05		Slope	370
Tunicate fields	Absence	Presence			4.2	Depth	126
Absence	920	34	954	0.04		BPI	104
Presence	8	38	46	0.17		Rock	88
Red algal reefs	Absence	Presence			13.5	Slope	442
Absence	3947	621	4568	0.14		Distance	412
Presence	55	393	448	0.12		Depth	382
Mixed faunal comm.	Absence	Presence			12.0	BPI	396
Absence	3891	649	4540	0.14		Depth	336
Presence	34	442	476	0.07		Rock	266
Sand with macro-fauna	Absence	Presence			10.7	Distance	424
Absence	3115	387	3502	0.11		Depth	316
Presence	14	240	254	0.06		BPI	286
Seafloor hardness	Sediment	Rock			12.6	Distance	361
Sediment	1278	224	1502	0.15		BPI	284
Rock	248	2006	2254	0.11		Depth	281

Average kelp densities were 20.3 m^{-2} individuals at Shag Rock and 24.3 individuals m^{-2} at Gull Rock (Table 5). Dense schools of pollock (*Pollachius virens*) and moderate densities of cunner (*Tautogolabrus adspersus*) were observed during dives at both sites. Due to the small number of quadrats and transects, further surveys are required to properly estimate the abundance of nekton within these habitats.

Red algae communities: Rock habitats between 28 and 45 m depth were dominated by dense foliose and filamentous red algae. These reefs were associated with sparse *A. clathratum*, byrozoans, sponges, and ascidians. Predictive distribution maps of the occurrence of red algal communities estimated that these habitats covered 5% of the total extent of the ESBA (Figure 5, Table 4). Misclassification rate for the RF model on occurrence of red algal reefs was 14 % (Table 5).

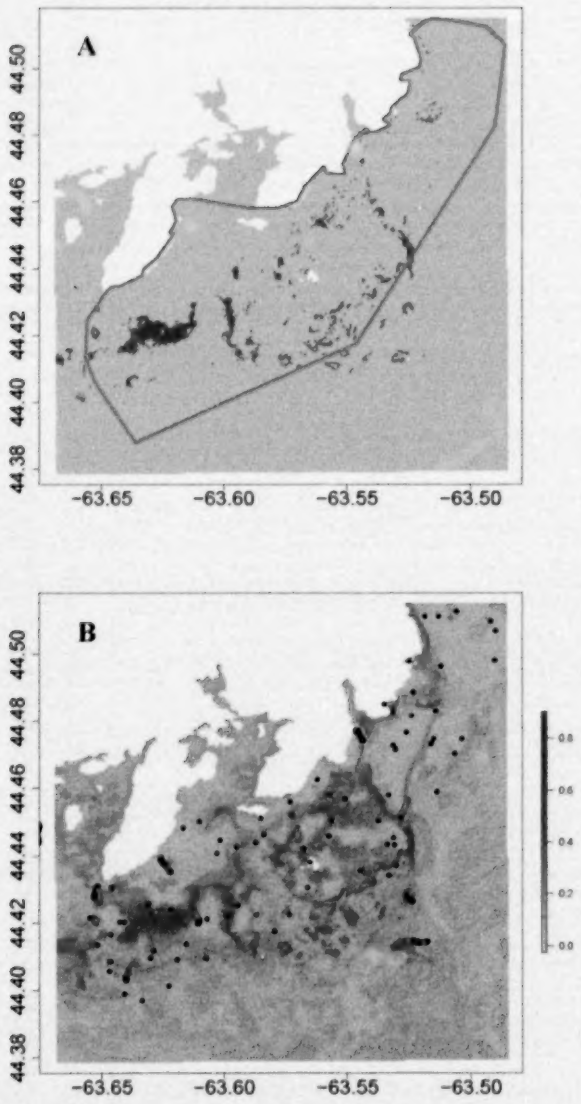

Figure 5. Predicted maps of foliose red algae habitat (blue). Maps show: A) the binary occurrence (presence/absence) of red algae-dominated reefs, which was used to assess model performance; and B) the probability of occurrence of red algae-dominated reefs, calculated as the proportion of trees in the RF model that classified a point as a presence. Red line shows bounds of EBSA. Points show locations of presence (red) and absence (black) observations from video surveys.

Table 5. Total nekton counts from dive surveys at kelp beds at Gull Rock and Shag Rock (2 x 30 m long transects of 2 m width for each site).

Site	Coordinates	Depth (m)	Cunner	Pollock	Lobster
Gull Rock	44 26.516	10	16	23	2
	-63 34.094				
Shag	44 25.827	8	1	210	0
Rock	-63 33.964				

Tunicates: Dense aggregations of stalked tunicates occurred between 27 and 62 m depth on bedrock (76% of all observations) or boulders (21% of all observations). The mean depth of tunicate aggregations was 42 ± 9 m. Tunicates were often associated with red algae (43% of observations), or mixed *A. clathratum* and red algae (11% of all observations). Other associations included sponges, soft corals, byrozoans, pollock and red fish (*Sebastes sp.*). Currently, the only other observations of dense aggregations of tunicates in Nova Scotia is about 1 km west of Sambro Islands and within the Bay of Fundy. Predictive distribution maps of the occurrence of tunicate fields estimated that these habitats covered an estimated 10% of the total extent of the ESBA (Figure 6, Table 4).

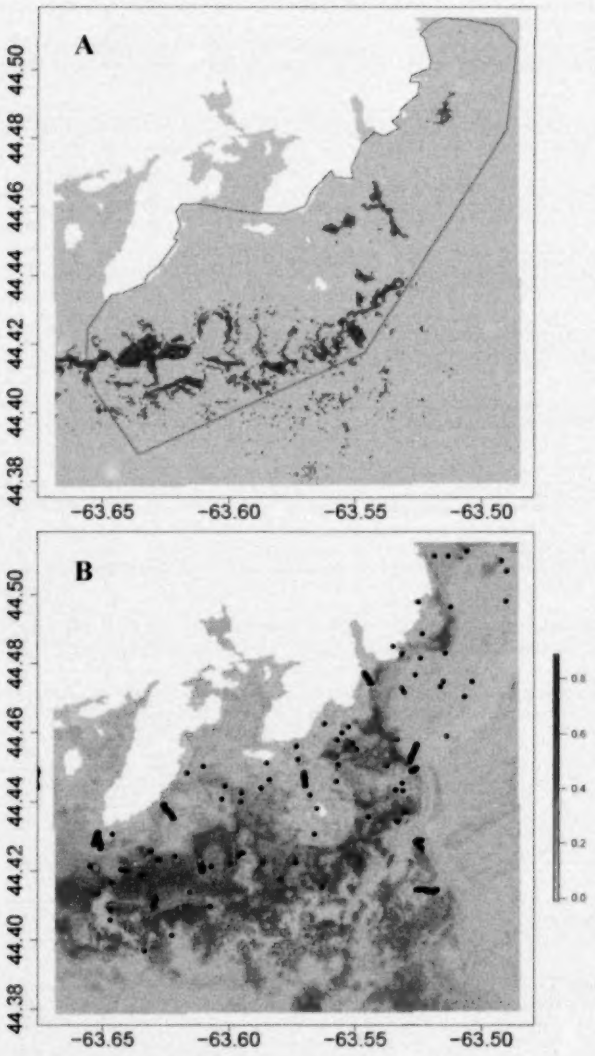

Figure 6. Predicted maps of tunicate fields (blue). Maps show: A) the binary occurrence (presence/absence) of tunicate fields, which was used to assess model performance; and B) the probability of occurrence of tunicate fields, calculated as the proportion of trees in the RF model that classified a point as a presence. Red line shows bounds of EBSA. Points show locations of presence (red) and absence (black) observations from video surveys.

Sponge, soft corals and ascidian communities: Circalittoral rock habitats often supported a dense mosaic of species, including sponges (*Halichondria spp. Leucosolenia spp.*, and *Microciona prolifera*), soft corals (*Alcyonium digitatum*), hydroids, byrozoans, and encrusting ascidian communities (*Didemnum spp. Halcynthia pryformis*, *Dendrodoa carnea*, *Mongola spp.*). Faunal communities on these reefs were highly variable and intermixed, making them difficult to classify into specific habitat types. These habitats occurred between 15 and 65 m depth, and were most common on boulders (41%) and

bedrock (36%). Predictive distribution maps of the occurrence of mixed faunal reefs estimated that these habitats covered 8% of the total extent of the ESBA (Figure 7, Table 3). Table 4 shows the accuracy measures for the random forest model on presence absence data of corals, sponges, and ascidians communities.

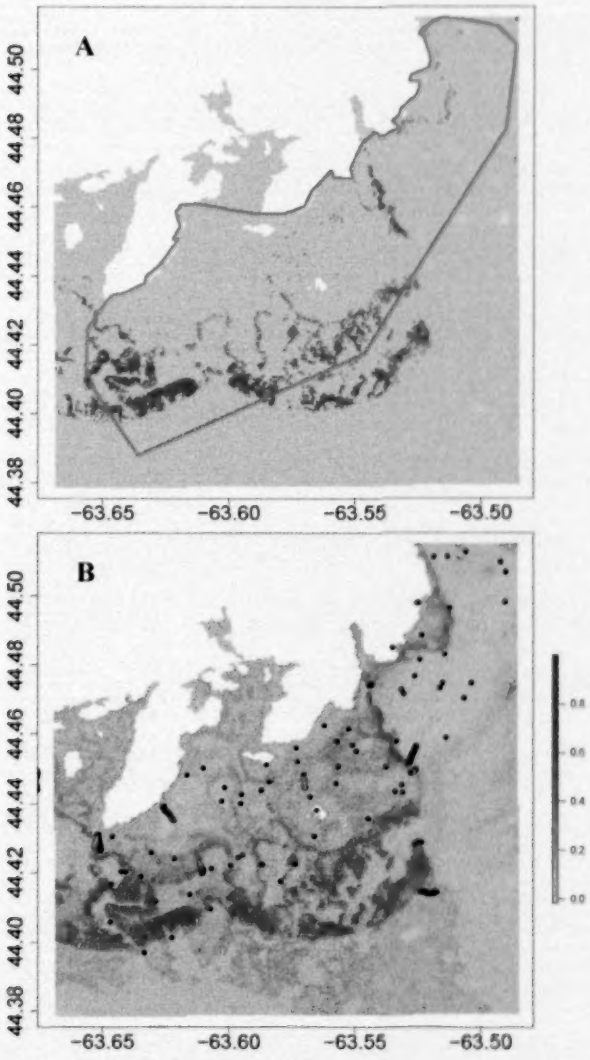

Figure 7. Predicted maps of deep rock habitat dominated by corals, sponges, and ascidians (blue). Maps show: A) the binary occurrence (presence/absence) of these mixed faunal communities, which was used to assess model performance; and B) the probability of occurrence of mixed faunal communities, calculated as the proportion of trees in the RF model that classified a point as a presence. Red line shows bounds of EBSA. Points show locations of presence (red) and absence (black) observations from video surveys.

BIOLOGICAL FEATURES ON SEDIMENT

Sedimentary habitats were observed across a range of depths (0–90 m), typically extending offshore from the deep margin of rock reefs. These habitats covered an estimated 45% of the EBSA. Coarse and fine sands were the most widely distributed sediment types across the study area, but cobbles, pebbles and mixed sediments (rock and sand) were also present. Most sediment habitats were devoid of macroalgae (91%). Shallow, infralittoral sedimentary habitats tended to be dominated by coarse sands, gravel or cobbles that were likely turned over with wave action. Lobsters were often observed in these habitats. Deep, circalittoral sedimentary habitats appeared relatively stable, with low wave action that allowed fine sediments to settle. Evidence of bioturbation in these areas indicates the presence of infauna, which could not be observed in video surveys. Sediment habitats with visible macrofauna covered an estimated 11% of the EBSA (Figure 8, Table 5). The most commonly observed macrofauna were brittlestars *Ophiopholis aculeata*, sand dollars *Echinarachnius parma*, and sea urchin *S. droebachiensis*. Purple sunstar *Solaster endeca*, snow crab *Chionoecetes opilio*, and various groundfish were also present in these habitats.

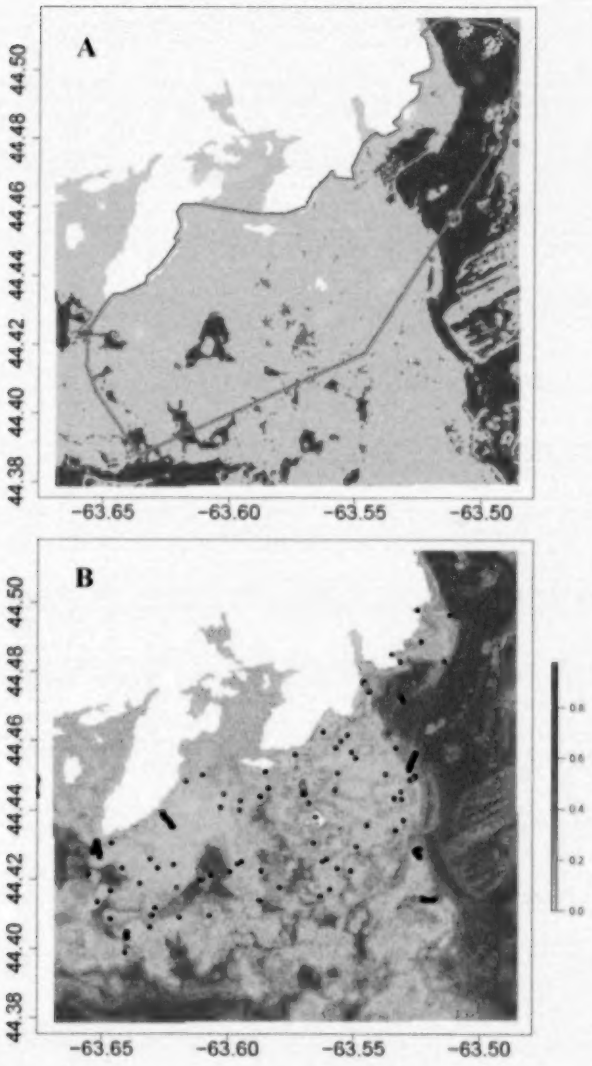

Figure 8. Predicted maps of deep sediment habitat with observed macrofauna (blue). Maps show: A) the binary occurrence (presence/absence) of these mixed faunal communities, which was used to assess model performance; and B) the probability of occurrence of mixed faunal communities, calculated as the proportion of trees in the RF model that classified a point as a presence. Red line shows bounds of EBSA. Points show locations of presence (red) and absence (black) observations from video surveys.

DIVERSITY OF BENTHIC HABITATS

The EUNIS classification system showed a diversity of benthic habitats and features within the Sambro Ledges EBSA (Table 6). High energy infralittoral rock within the EBSA typically supported multiple different macroalgal communities that were sometimes overgrazed by the green sea urchin *Strongylocentrotus droebachiensis* (Figure

9). At deeper depths beyond the infralittoral zone, the circalittoral zone was split into two sub-zones; upper circalittoral (foliose red algae present but not dominant) and deep circalittoral (foliose red algae absent). Circalittoral rock habitats were characterised by a variety of animal dominated communities (Table 6, Figure 10).

Table 6. Benthic habitats observed within the Sambro Ledges EBSA. Habitat types are based on EUNIS classification system. Description of North Atlantic habitat types and prevalence (percentage of observations from all video surveys) are included. Note: video transects were targeted for rock bottoms, so the prevalence of these habitats is likely an over-estimate of their actual abundance within the EBSA.

Level	EUNIS code	Unit designation	Prevalence (%)
3	A3.1	Atlantic high energy infralittoral rock	25.0
4	A3.11	Kelp beds	20.4
5	A3.113	*A. clathratum* with and foliose red seaweeds on exposed infralittoral rock	4.4
5	A3.115	*Laminaria digitata* on very exposed infralittoral rock	6.5
5	A3.116	Mixed *L. digitata* and *S. latissima* on exposed infralittoral rock	6.0
5	A3.118	Mixed *S. latissima* and *A. clathratum* on exposed infralittoral rock	7.7
5	A3.131	Sea urchin barrens, overgrazed infralittoral rock with incrusting coralline algae and sea urchins	0.02
4	A3.12	Sediment-affected or disturbed kelp and seaweed communities	0.01
5	A3.124	Dense *Desmarestia* spp. on exposed infralittoral rock	<0.01
5	A3.125	Mixed kelps with foliose red seaweeds on infralittoral rock	0.01
5	-	Turf forming algae on infralittoral rock.	0.1
5	A3.215	Dense foliose red seaweeds on infralittoral rock	5.1
3	A4.1	Atlantic high energy circalittoral rock	28.8
4	A4.12	Sponge communities on deep circalittoral rock	2.9
4	A4.13	Mixed faunal turf communities on circalittoral rock: hydroids, bryozoans and sponges	4.7
5	A4.212	Corals, sponges and crustose communities on circalittoral rock	4.7
5	A4.213	Anemone and sand-tolerant fauna on circalittoral rock	0.7
5	A4.214	Sea urchin barrens with crustose communities on circalittoral rock	8.5
4	A5.13	Infralittoral coarse sediment	0.2
4	A5.14	Circalittoral coarse sediment	2.9
4	A5.15	Deep circalittoral coarse sediment	2.7
4	A5.23	Infralittoral fine sediment	0.03
4	A5.25	Circalittoral fine sediment	16.3

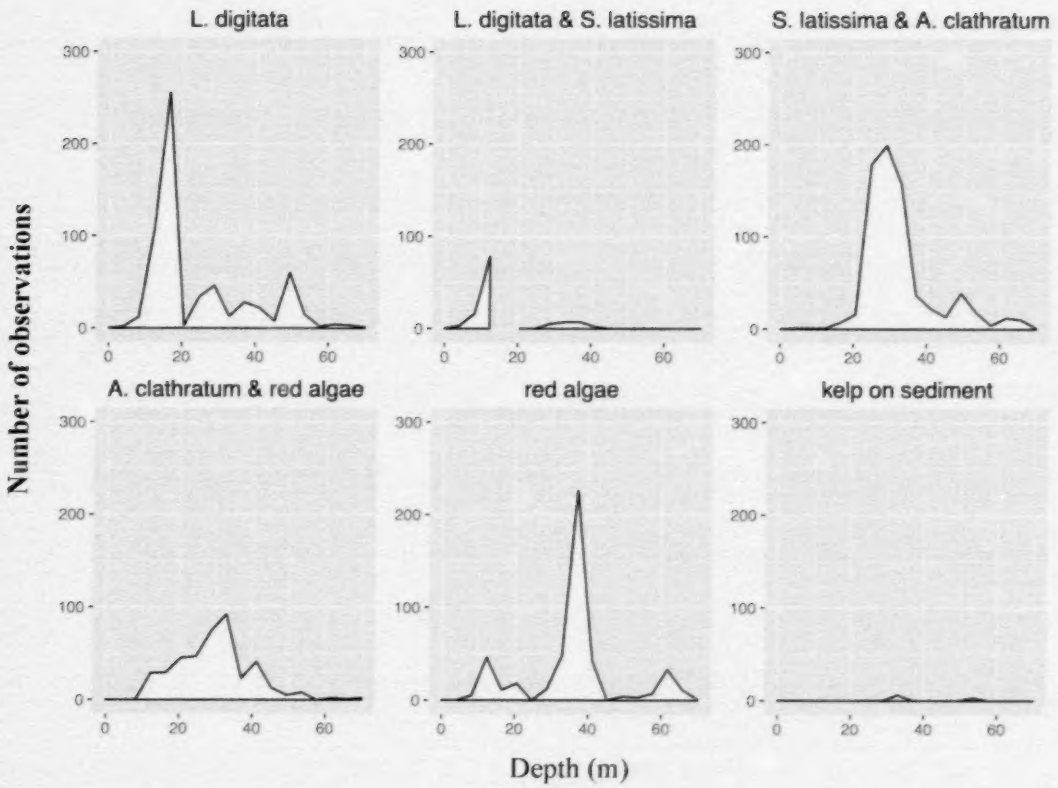

Figure 9. Abundance of algal communities across depth.

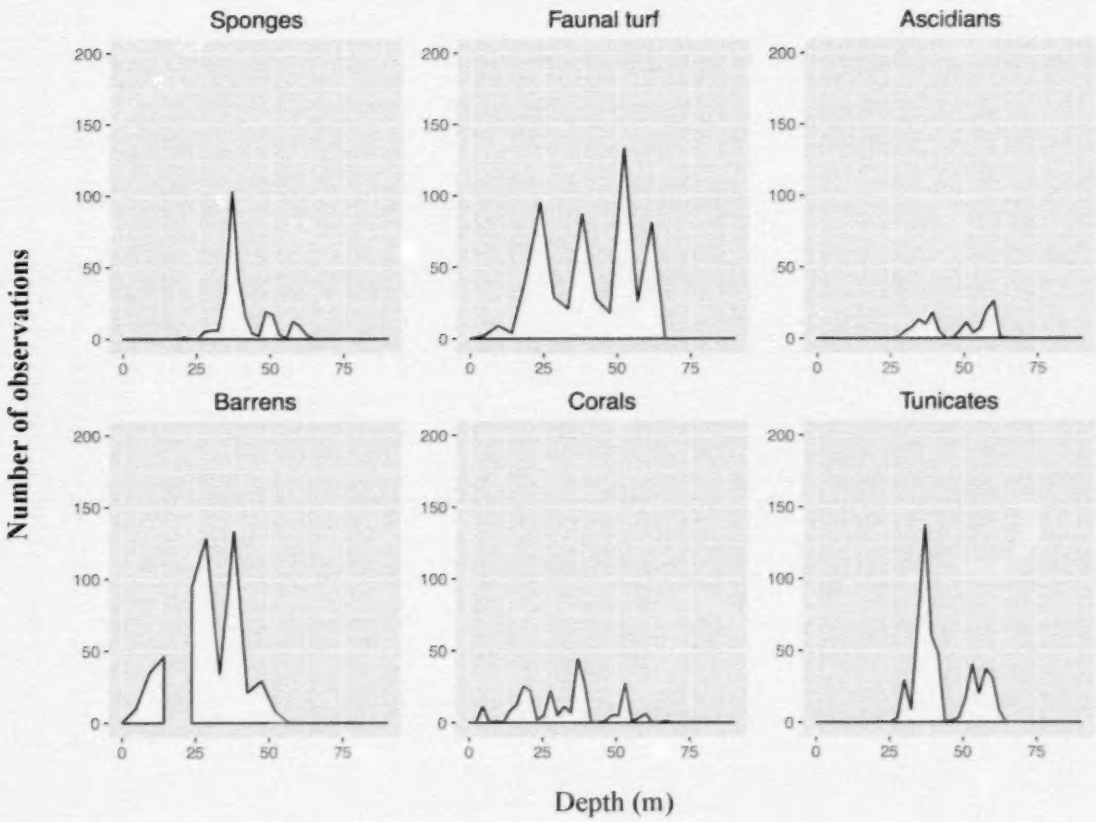

Figure 10. Abundance of faunal communities across depth.

Sea urchin barrens were mainly found between 15 and 40 m depth. These habitats were dominated by *Strongylocentrotus droebachiensis*, which graze standing macroalgae leaving bare coralline algal crusts. Sea urchin barrens were too sparse to be accurately mapped and were probably rare because of the disease *Paramoebiasis*, which causes mass mortality of sea urchins at depths shallower than 12 m. Rock reefs dominated by the horse mussel *Modiolus modiolus* were observed between 25 and 40 m depth. These reefs were also too sparse to be accurately mapped.

DISCUSSION

The Sambro Ledges EBSA contains a variety of habitat types and unique features. This high diversity may be due to the many structurally complex rocky reefs, shoals, and ledges within the EBSA. Abundant kelp beds and other seaweed-dominated communities are indicative of high primary productivity within this area. Macroalgal beds are important coastal ecosystems that are used as nursery habitats for commercial fish and other species (Christie et al. 2009) and supply food to adjacent habitats through export of detrital material (Krumhansl and Scheibling 2012). The kelp cover within the Sambro Ledges EBSA was high compared to kelp beds along other parts of the Atlantic coast, which are becoming increasingly degraded due to warming sea surface temperatures and invasive species (Filbee-Dexter et al. 2016). It is possible that kelp beds on these ledges are more resilient to regional ocean warming because they experience colder temperatures and increased water movement compared to kelp beds in sheltered regions (Filbee-Dexter et al. 2016).

Other important habitats found within the EBSA were fields of stalked tunicate *Boltenia ovifera*. These biogenic habitats exist at greater depths than kelp beds and support high abundances of epiphytes and other fauna (Francis et al. 2014). Dense aggregations of *Boltenia ovifera* have been identified as indicators of vulnerable marine ecosystems (NAFO 2013). Tunicate fields are rarely observed along the coast of Nova Scotia, so inclusion of the Sambro Ledges EBSA in a regional MPA network would ensure that a representative example of this habitat is protected. Deep rock reefs dominated by corals, sponges and other faunal communities were also abundant within the Sambro Ledges EBSA. The extent, function and uniqueness of these habitats compared to other areas of the coast are unknown, but they likely contribute to high diversity of species and habitats within the area.

Obtaining data on biodiversity is an important step in designing the coastal component of the MPA network. In this report, habitat diversity was used as a proxy for biodiversity of benthic communities because it can be more easily estimated from observations of the seafloor, and there is a strong association between habitat complexity and biodiversity (Kovalenko et al. 2002). The habitat classification scheme developed in this report uses a hierarchical system that initially classifies benthic habitats by energy level, bottom type and depth (e.g. high energy, infralittoral rock). These data are usually readily available and accurately predicted the occurrence of many benthic habitats in the Sambro Ledges EBSA. Time intensive *in situ* observations are required to resolve the seafloor into more detailed categories according to dominant species, communities or detailed information regarding substrate.

To summarize the distribution and abundance of benthic habitats within the Sambro Ledges EBSA, a combination of pre-existing field observations, randomized surveys, bathymetric maps, and spatial models was used. This enabled a cost-effective and reasonably comprehensive summary of the area. A random point survey approach was an efficient way to collect sufficient benthic data to map the areal extent of different features, which is useful for management. Targeting further surveys to non-uniform

features (such as high slopes, ranging depths, or unique topography) will ensure that rare biogenic habitats and communities are more likely to be captured. It is important to reiterate that the spatial models presented in this report only provide an estimate of the potential distribution of each habitat type within the area of interest. Although these predictive models are useful tools for filling in spatial gaps between observations and estimating the areal extent of different features, they should not replace observational fieldwork. As was the approach for this study, predictive models should supplement observations of dominant habitats, community composition and measures of diversity obtained from the field. Decisions made using these models should consider the potential for bias and error associated with the estimates.

CONCLUSIONS AND RECOMMENDATIONS

RECOMMENDATIONS FOR ADJUSTMENT OF EBSA BOUNDARIES

The current bounds of the Sambro Ledges EBSA could be adjusted to better encompass ecologically important habitats and features. Habitat complexity and diversity was highest in the southwestern part of the EBSA, where tunicate fields, kelp beds, sponge and ascidian communities, and structurally complex reefs were abundant. The bounds of the Sambro Ledges EBSA do not fully encompass these habitats, which were also observed south of Pennant. In contrast, the benthos in the northeastern regions of the EBSA was more uniform, and observations of sedimentary habitats in this region were similar to those observed along other parts of the Scotian Shelf (Filbee-Dexter and Scheibling 2016). Inclusion of habitats in both regions is important. Therefore, it is recommended that the easternmost extent is reduced, and the bounds west be expanded to encompass the reefs surrounding Pennant. Areas around Duncan's cove should be maintained in the EBSA due to high habitat diversity in the nearshore area.

RECOMMENDATIONS FOR FURTHER DATA COLLECTION

The current understanding of the benthic habitats within the Sambro Ledges EBSA far exceeds available data for many other coastal areas being considered for inclusion in the larger MPA network. While additional observations of the seafloor for this EBSA would increase our understanding of these habitats, the priority should be to undertake similar sampling in other EBSAs along the coast. This will enable assessments of connectivity among habitats and ensure that representative examples of different ecosystems and communities are included in the network. One caveat to this approach is the lack of knowledge of the fish and infaunal communities within the Sambro Ledges EBSA area. In addition, oceanographic data such as bottom currents, temperature, and light would also help classify benthic habitats, and could be used to refine predictive models. These data will be invaluable for determining whether to include this area in the MPA network.

Recommendations:

1. Better resolution of substrate type is needed for coastal habitats. Priority should be given to collecting and analyzing backscatter or multi-beam sonar data, and refining current maps of bottom type along the coast.

2. Baseline ecological data within EBSAs should be collected using sampling designs that enable predictive mapping.

3. Data collection in other EBSAs should be prioritized over further sampling of the Sambro Ledges EBSA.

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